Chemical and Biological Threat-Detection

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The Science and Technology (S&T) group of the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) Software Support Activity (SSA) provides technical expertise for the transition of Information Technology (IT) S&T products into JPEO-CBD programs. Efforts are underway throughout the nation to advance the state-of-the-art of Chemical, Biological, Radiological and Nuclear Defense (CBRND) systems. This article explains some of the technology involved in advancing and integrating major thrusts. One is the development of new, next-generation individual and arrayed chemical and biological sensors. The other is the integration of these sensors into a network in which intelligent software agents, data-fusion algorithms, and expert systems can enhance the user's ability to retrieve and understand the data, and to act efficiently on the results.

Various research projects also can be applied to improvised explosive device (IED) detection, which is difficult due to the many forms in which they can be manufactured and deployed.

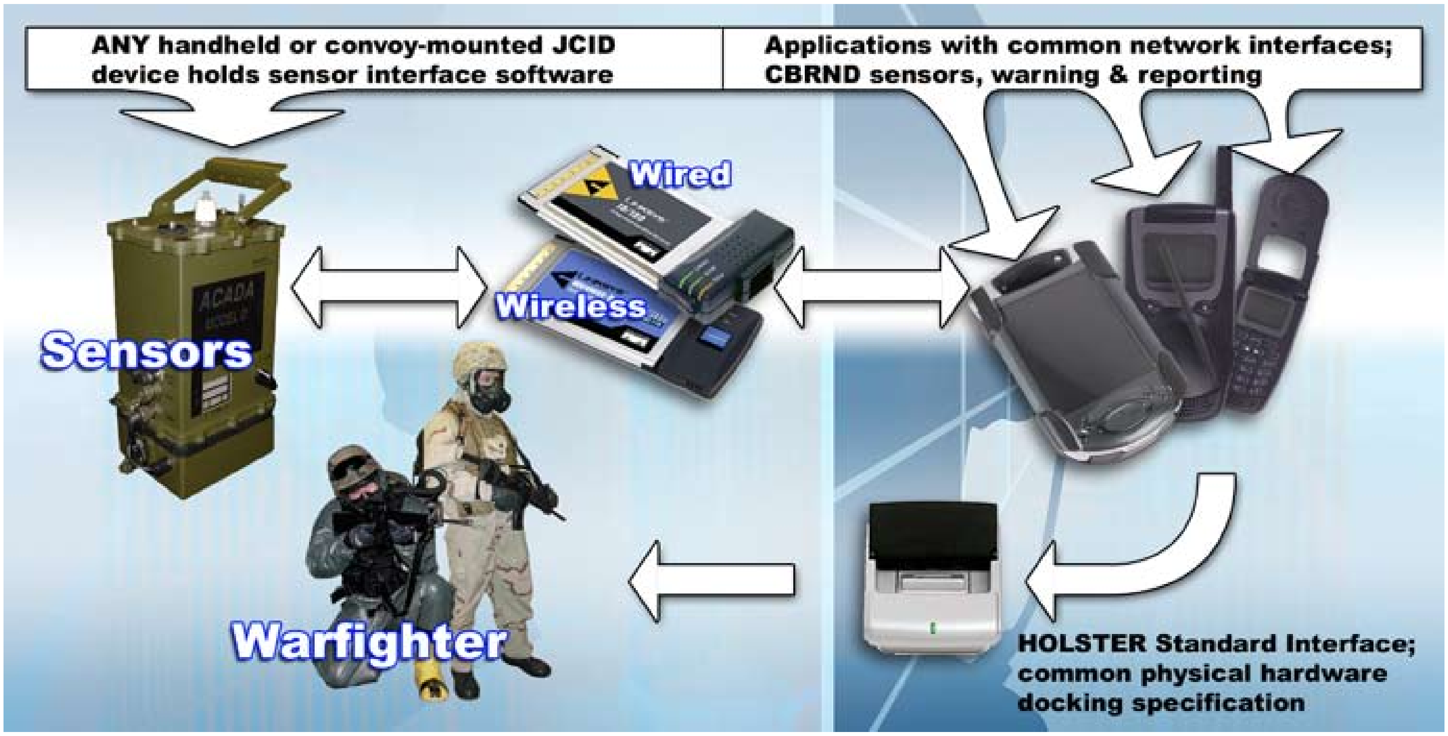

FIGURE 1: JCID/Holster sensors and their interfaces implemented with Personal Computer Memory Card International Association (PCMCIA) external / internal "cards" independent of specific platform using wired or wireless networks.

development of the ultra-sensitive Surface-Enhanced Raman Spectroscopy (SERS)-based hardware, the Knowledge Amplification by Structured Expert Randomization (KASER) anthrax detector, the Joint Warning and Reporting Network (JWARN) Component Interface Device (JCID)-on-a-chip firmware, and the Holster sensor-network infrastructure. This research has two However, they all have explosives that emit gases subject to detection. This research can lead to the technology transition of efficient methods of detecting these gases rapidly enough for the Warfighter to take evasive action. Lighter, smaller, less-power-hungry CBRND sensors are needed. One operational application is to provide convoys small, portable devices

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14. ABSTRACT
Published in Chem-Bio Defense Quarterly, Apr - Jun 2007, Vol. 4, No. 2, pp. 18-21. This article explains some of the technology involved in advancing and integrating development of the ultra-sensitive Surface-Enhanced Raman Spectroscopy (SERS)-based hardware, the Knowledge Amplification by Structured Expert Randomization (KASER) anthrax detector, the Joint Warning and Reporting Network (JWARN) Component Interface Device (JCID)-on-a-chip firmware, and the Holster sensor-network infrastructure. This research has two major thrusts. One is the development of new, next-generation individual and arrayed chemical and biological sensors. The other is the integration of these sensors into a network in which intelligent software agents, data-fusion algorithms, and expert systems can enhance the users ability to retrieve and understand the data, and to act efficiently on the results.

15. SUBJECT TERMS
chemical and biological sensors; data fusion; Knowledge Amplification by Structured Expert Randomization (KASER)

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Systems of the Future

that use commercial off-the-shelf (COTS) compact, wireless technology. The Warfighter can customize and modernize these new capabilities independently of other capabilities. For example, since the detectors are lightweight and require low power, power capabilities and capacities of vehicles do not need modifications to accommodate them. Warfighters in the infantry can carry them into battle easily using the equipment with which they already deploy. Other possible applications that have significant technology transition potential include deployment of lightweight, low-power sensors on Unmanned Airborne Vehicles (UAVs) without affecting the power requirements of the UAV propulsion systems. Moreover, arrays of these sensors can act in concert providing more powerful capabilities than individual sensors. Miniaturized hardware will achieve this degree of integrated small-footprint capability. Future research will incorporate new sensor miniaturization technology. The transition of the technology in this research is aimed at supporting convoy and individual safety on the battlefield.

JCID-on-a-Chip and Holster

The first technology is the JCID-on-a-chip software technology represented in Fig. 1. David Godso (JPEO-CBD), Charles Datte (then of Sentek Consulting), Ritesh Patel (SSA), Francesca Mirabile (former member of SSA architecture team) and Jeffrey Steinman, Ph.D. (CEO WarpIV Technologies, Inc.), have described network-ready CBRND sensors in an Institute of Electrical and Electronics Engineers (IEEE) conference paper, and are points of contact for this technology. "JCID-on-a-chip" is the subject of a current project to develop a software-

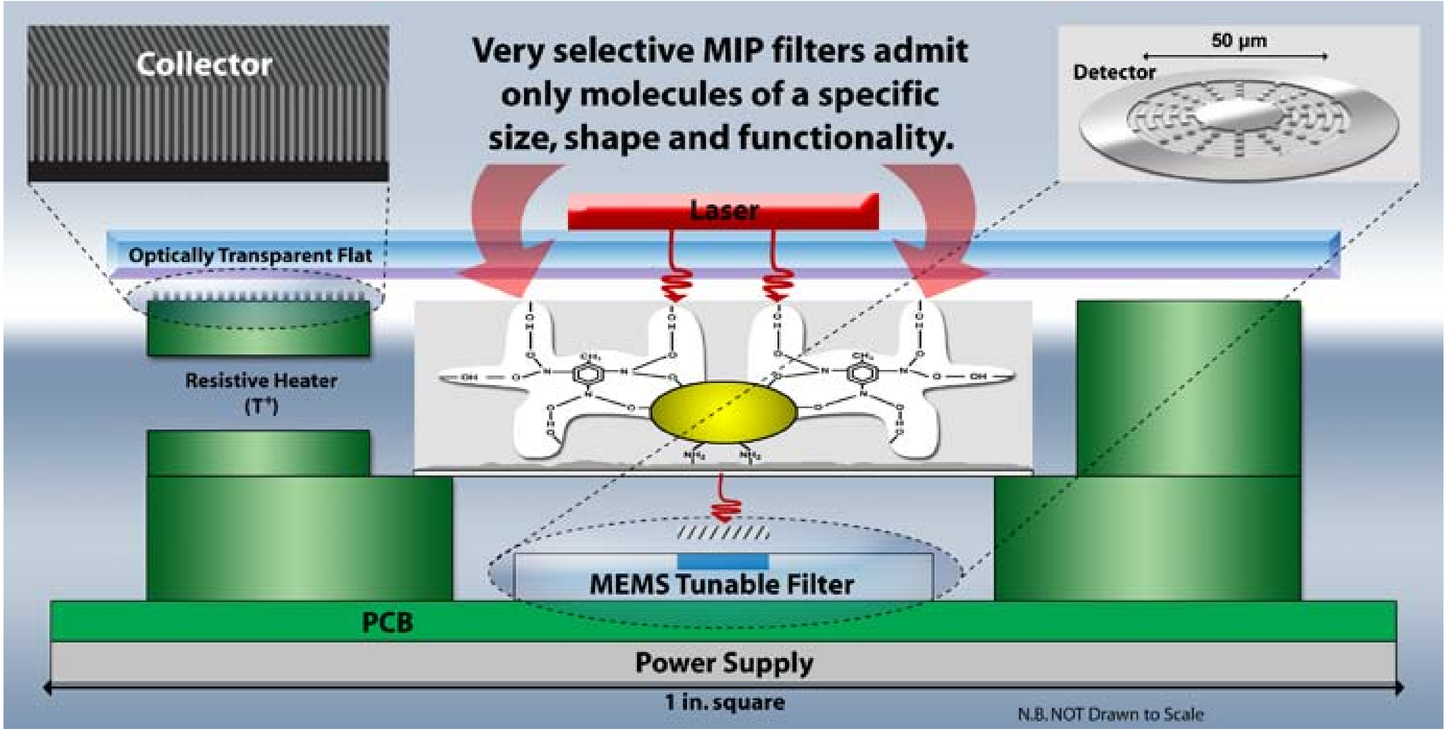

FIGURE 2: Fabry-Perot sensor with combine MEMS tunable optical filters with MIPs for SERS. (U.S. Patents 6,581,465, 6,550,330, 6,546,798 and 6,763,718; Navy Case Nos. 96659, 84769, 84715, 84774, and 98184)

defined sensor concept, architecture and approach to modular CBRN and Explosives (CBRNE) sensors. Thus, any hardware devices can be used in a “plug-and-play” mode. JCID can support the ability to load to field-programmable, gate-array-supported sensor hardware platforms as well as other types of software-based chip sets.

Holster is a key component in the network-centric CBRNE information technology of the future because it provides a common interface for many different types of sensors, some of which are still under development. Holster represents an important step forward in modular information technology management. Future systems will need this plug-and-play capability because the sensors can be developed independently of the information system that uses their data. Not only sensors, but also software, such as user-interface applications, network-centric data-fusion applications, their transition environments and other network-centric applications can be developed independently by different groups and integrated using the common Holster standard interface. This represents a significant cost savings because it obviates the necessity to retrofit applications so they can interoperate in the net-centric environment.

SERS-Based Micro-Electro-Mechanical Systems (MEMS) Sensor System

Pamela Boss, Ph.D. and Richard Waters, Ph.D. are two researchers who are developing an exciting class of key sensors that can detect both chemical and biological threats. These sensors use coupled-cavity Micro-Electrical-Mechanical Systems (MEMS) (U.S. Patents 6,581,465, 6,550,330, 6,546,798 and 6,763,718; Navy Case Nos. 96659, 84769, 84715, 84774, and 98184) in a small (<0.5 in^3), low-cost, highly sensitive less than parts per billion (<ppb), reliable device capable of nearly real-time (<60 sec.) simultaneous detection of multiple chemical and biological agents. The technology combines novel MEMS dual-cavity Fabry-Perot spectrometer design with Molecular-Imprinted Polymer (MIP) coating for Surface-Enhanced Raman Spectroscopy (SERS) analysis, as illustrated in Fig. 2. The same easily deployable automated system will be reconfigured to detect new chemical and biological threats, and possibly nuclear threats. The spectrometer consists of a monolithic implementation of Fabry-Perot interferometer and a photodiode on the same integrated circuit substrate. The interferometer uses two parallel and optically flat mirrors separated by an air gap. When light of a specific wavelength shines on the surface of a resonance-configured mirror, most of light is transmitted through the interferometer. If all of these conditions described above are not met, hardly any light is transmitted. For example, if the wavelength or the spacing between the mirrors is altered, far less light is transmitted, thus decreasing the associated current in the photodiode that collects the transmitted light and converts it into electrical current. Therefore, the change in photodiode current is related to the change in mirror displacement, and hence, a change in spectral intensity at the specific wavelength. The spectrometer hardware demonstration will include fabrication of the MEMS-based spectrometer and the creation of the SERS-active coatings using MIPs.

Because the SERS-MEMS sensors produce data that can be sent anywhere, they will fit into the Holster standard-interface architecture. The transition of these sensors will give convoys and individual Warfighter a significant edge in their detection capabilities without adding additional significant weight.

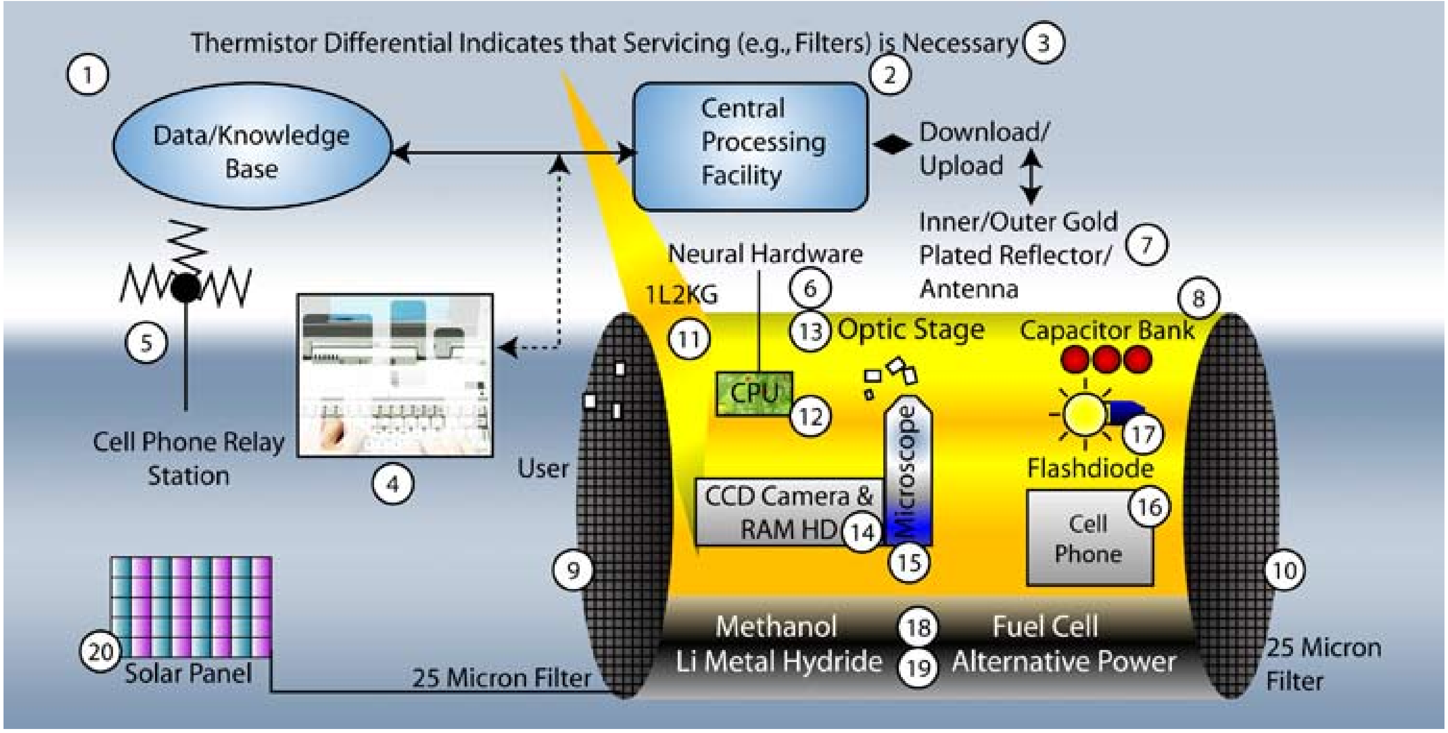

FIGURE 3: KASER sensor for anthrax and IED detection. Data are fused using a knowledge amplifier for more sensitivity than that of individual sensors as automatic feature extraction increases gain. U.S. Patents 7,006,923 and 7,082,369.

KASER-Based Anthrax Detector

Stuart Rubin, Ph.D. is another scientist who is working on a different type of next-generation sensor to detect biological threats using KASER technology (U.S. Patents 7,006,923

and 7,082,369). This sensor, which is depicted in Fig. 3, can be modified to detect chemical threats associated with IEDs. The increased sensitivity of these sensors is due to amplified detections using innovative artificial-intelligence and data-fusion techniques. Automated feature extraction increases gain to outperform current technologies. The evolutionary feature of the learning system allows for detection of new explosive formulations. Signatures can be communicated via radio or cell phone. A processing facility collects the reports from each deployed unit. These reports, which are downloaded automatically, are saved in a database where they are mined periodically (e.g., hourly) to discover pattern anomalies.

The patterns generated by these distributed sensors are analyzed using a knowledge-based inference engine, such as a KASER to pinpoint the sources and causes of contamination and to predict the areas in need of evacuation or other counter-measures. This function will support and interoperate with JWARN. The KASER detector system can fuse multiple heterogeneous sensor data observed weather patterns, satellite imagery, passenger flight manifests and intelligence reports. The system can operate in extreme climates unattended for at least a month powered by solar, battery or fuel cells. The cost of fabricating custom integrated circuits will not be incurred because high-speed, wide-bus chips will be programmed with Dr. Rubin's patent-pending improvement invention for the patented KASER algorithm for performing network-centric sensor fusion.

Currently available CBRN sensors have widely varying interfaces making system integration and networking complex. Progress in software radio technology has demonstrated that updatable and reconfigurable hardware devices can be built to support a variety of different digital circuit and interface protocol implementations. They accomplish this by downloading and booting firmware into the field-programmable memory and gate array integrated circuits within the device. The same technology can be used to solve the CBRN sensor integration problem. Software will allow configurable I/O translation modules to be loaded dynamically into the final hardware platform, which also will contain the Ultra-Sensitive sensors based on MEMS technology and other highly sensitive sensors, such as the KASER anthrax detector. Future research will extend the JCID-on-a-chip effort to exploit these combined technologies in a common data backbone using the Holster common interfaces in a net-centric environment. KASER intelligent sensor-fusion applications can process data from a wide variety of sensors, not just the anthrax detector. The intelligent network centricity in the KASER design will result in better, more advanced data-fusion applications to assist the Warfighter in understand situations and threats.

The wireless firmware-reconfigurable JCID sensors will be integrated with the MEMS spectrometer, KASER system in a supporting environment called Holster. Holster provides hardware packaging and connectors, electrical power, and common services including plug-and-play configuration, communication protocols, information assurance, and wireless networking infrastructure to integrate CBRN sensors. Holster supports scaleable and upgradeable modules through a software-based approach, all evolving toward a common sensor platform baseline that can accommodate any CBRNE sensor in a plug-and-play architecture. The demonstration will include the ability to use any configuration of JWARN sensor network; the ability to deploy sensor networks of different configurations; and the ability to share sensor data simultaneously with JWARN and other CBRN users on the fly without interrupting other applications to support a net-centric environment. Successful development and integration of these sensors will result in a revolutionary system for chemical-biological identification with performance far superior to current systems. The final integrated devices will be lightweight, low cost, deployable in arrays and capable of detection with little temperature or humidity sensitivity with potential operational applications in decontamination monitoring as well as in predictive analysis.

Because the SERS-MEMS sensors produce data that can be sent anywhere, they will fit into the Holster standard-interface architecture.

The Need Continues for Joint Chemical and Biological Research

Meriah Arias-Thode, Ph.D., of the JPEO-CBD SSA S&T group attended the Association of the United States Army conference in Washington, D.C. October 9-12. During the conference, she talked with several personnel working on chemical and biological defense. For example, she learned: 1) The real topic of concern is chemical and biological hazards as well as toxic industrial chemicals and materials, which appear at this time to be more of a threat than are nuclear weapons and 2) The Army needs improvements in chemical and biological defense. JPEO-CBD and the SSA S&T group continue to pursue improvements in CBRND systems through the introduction of new technologies. For more information, please contact the SSA S&T Lead, Dr. LorRaine Duffy, lorraine.duffy@navy.mil.